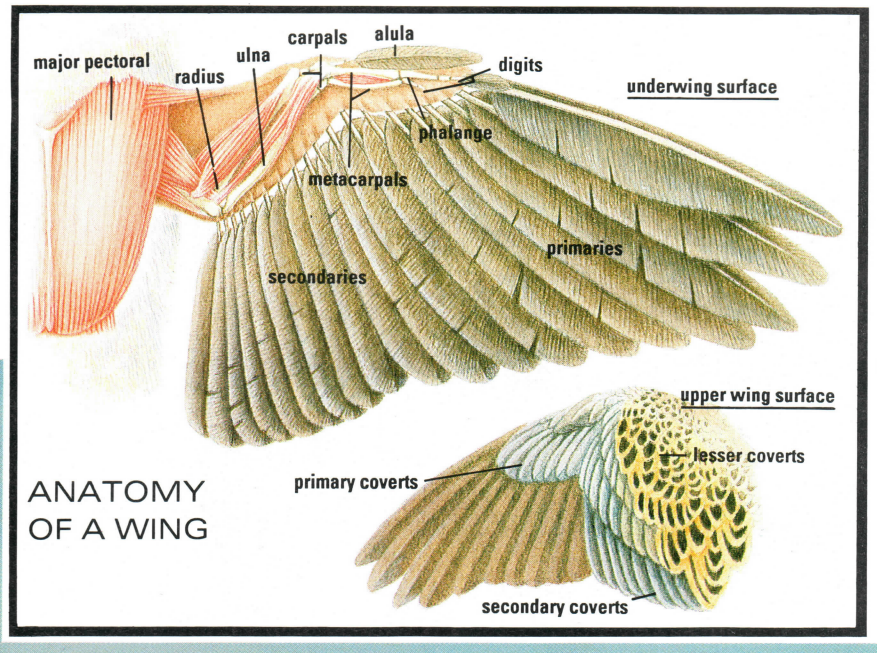
NATURE'S FLYING MACHINES



ANATOMY OF A WING

M. Danegger/Jacana/Mark Iley

Skidding along *on its feet, a swan uses its body and wings as airbrakes after a rapid descent on to the water.*

BIRDS, BEES AND BATS – ALL have evolved well equipped for flying, their skeletons perfectly adapted to aerodynamic necessities.

Birds are able to fly because of three important adaptations of their skeletons. First, they have an immensely strong but very light bone structure. Second, the skeleton has adapted to house relatively large and powerful chest muscles that work the wings. Third, the elongated 'arm' and 'hand' bones, making up the wing, are covered by a large surface area of close-fitting feathers – and it is feathers that are the key to flight.

Feathers are of immense importance to a bird – they complement the skeletal adaptations. Down feathers keep the bird warm, flight feathers enable it to fly, and contour feathers provide warmth, protection and coloration. Feathers are amazing structures, made up of a very light and rigid central shaft, which has small barbs projecting from each side. These barbs have tiny branches emerging from them called

Just amazing!

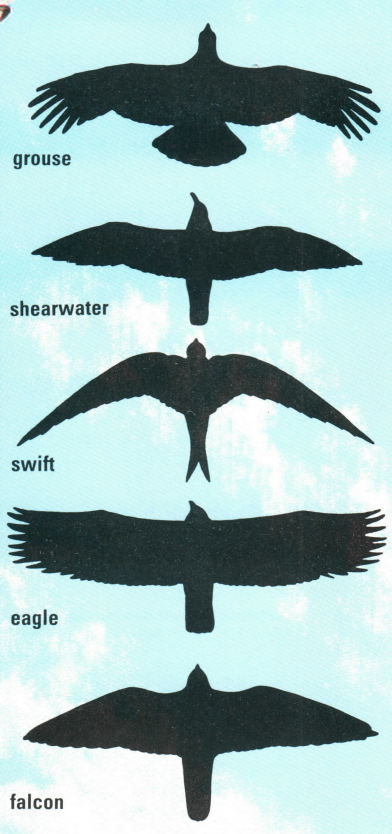
NEVER-ENDING JOURNEY

ONE BIRD, THE SOOTY TERN, CAN FLY FOR UP TO FOUR YEARS WITHOUT EVER LANDING ON SEA OR LAND, FEEDING AND SLEEPING ON THE WING.

Paul Raymonde

WING SHAPES

Hans and Judy Beste/Ardea



The wing shape of a bird in flight is one of the key features to identifying it. Birds' wings are adapted to their individual lifestyles. Grouse, for example, are essentially ground dwellers, only taking to the air if they sense danger. Their broad wings are ideal for rapid take-off. The shearwater is a glider – long thin wings enable it to glide effortlessly over the sea. The swift, on the other hand, needs manoeuvrability and its swept back wings and forked tail provide this. The eagle's broad wings give maximum lift and the spread out primaries control flight – essential for a species that lives by hunting. The slim, pointed wings of the falcon provide speed, allowing this species to travel at over 300 km/h, making it the fastest bird in existence.

feathers. These help to control flight at slow speeds – like wingflaps in aircraft. Turning is achieved by tilting the body and using the tail as a rudder.

Staying aloft

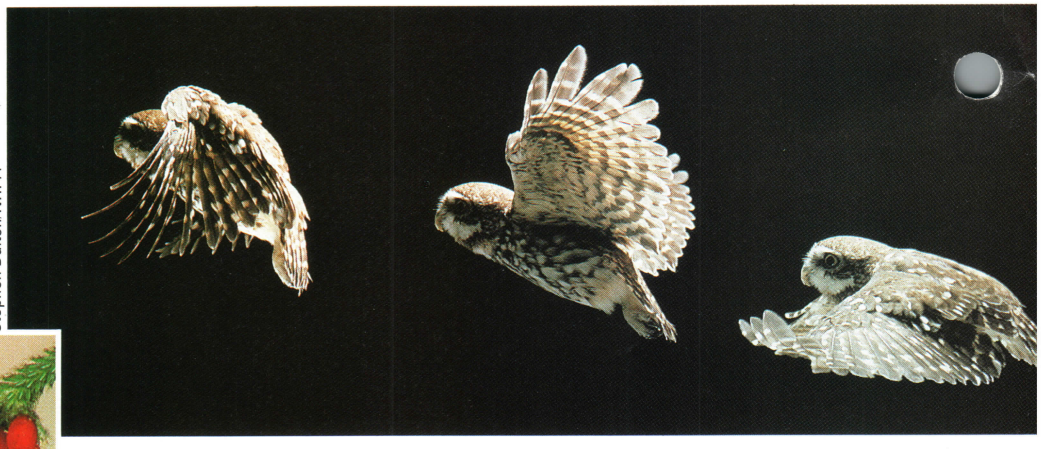
Because of their differing habits and life-styles not all birds fly in the same way. And different species have evolved different wing and body shapes. For example, swept back wings and forked tails are likely to belong to fast-flying birds that need to be highly manoeuvrable in the air – such as swifts, who catch their insect food on the wing. But birds with big wingspans are likely to be gliders, often seabirds, such as shearwaters.

Some birds spend most of their time on the ground and take to the air only to avoid danger – gamebirds and rails belong to this group. Such birds have broad, rounded wings, which allow a fast takeoff and rapid acceleration, but do not permit sustained flight.

Long broad wings with spread primaries usually belong to soaring birds. These allow the birds to take maximum advantage of rising air currents, and so species such as eagles can fly for long periods, without having to use energy beating their wings to stay aloft.

Silence in flight *is a prime requirement for a hunter of the night. Long bristles that extend beyond the feathers on the owl's wings eliminate any flapping sounds, enabling it to pounce on its prey without warning.*

The sunbird *is able to hover by putting all its flying effort into getting lift rather than forward movement.*



Stephen Dalton/NHPA

J. J. Brooks/Aquila

barbules. The barbules are locked together, by means of tiny hooks (barbicels) and so the feather is united into one very smooth, very strong surface.

How birds fly

The feathers of the wings and tail control the bird in flight. Wings have three sets of flight feathers. The first group, the primaries, are used to move the bird forwards and control flight. The primaries are closed as the wing moves downwards, displacing a large volume of air – the power stroke. As the wing moves upwards, the primaries are opened out, so as not to cancel out the 'pushing' effect of the downward stroke.

The next group of wing feathers are the secondaries, which provide lift. The third group are the alula

The most effective use of air currents, however, takes place over the sea. Because of frictional resistance between the air and the sea surface, the air in a wind travels slower, the closer it is to the sea. Large gliding birds, such as albatrosses and fulmars, use these conditions to sail in a series of regular circling movements.

They move down-wind losing height and then turn up-wind to gain height, by entering a faster moving layer. This all takes place within 20 metres of the surface of the sea and can continue for many hours with only occasional wing beats. Gulls following ships also make use of the local upcurrent created by the movement of the vessel.

Accurate determinations of the speed of bird flight are hard to

Stephen Dalton/NHPA

***Locusts** are the most destructive insects in the world, eating their own weight in food each day. In Ethiopia, one swarm took six weeks to destroy cereals sufficient to feed a million people for a year. The greatest swarm ever recorded covered 5,180 km.*

so they can beat their wings rapidly.

The wing-beating record for insects is held by the midge, which beats its wings over 1,000 times per second. This compares with just 90 times per second for the South American horned sungem bird. The slowest insect wing beat is that of the Swallowtail butterfly at a mere five beats per second.

The rate at which energy is converted is called the metabolic rate.

Stephen Dalton/NHPA

***The flying beetle** has brightly spotted casings to protect its wings when not in flight. The bright colours act as a warning to other species that the beetle is poisonous or has a deadly sting.*

obtain. The smaller perching birds, such as sparrows, fly at between 30 and 50 km/h, while migrating ducks may reach speeds of around 80 km/h. The normal speed of a racing pigeon is also thought to be around 80 km/h. The fastest of all birds is said to be the peregrine falcon. An experiment carried out in Germany has shown that a peregrine reaches speeds of between 270 and 320 km/h when swooping on prey.

As a result of sightings from aircraft and radar, there is more information available about the heights at which different birds fly. Most birds keep well below 150 metres during normal local movements, but they may fly much higher during migration. Migrating wading birds have been observed at heights of at least 6,000 metres. Smaller migrants, such as perching birds, cannot reach such heights — they rarely fly above 1,500 metres.

Flying insects

Another important group of natural fliers are insects. They have very efficient bodies for flight. Their short, thick muscle fibres and short connecting nerves transmit impulses to the muscles very quickly

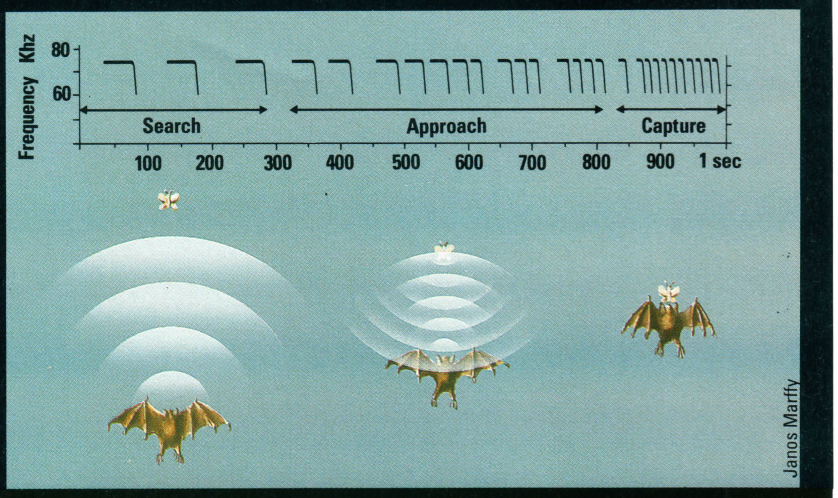
BUTTERFLY TRACKS

The monarch butterfly is one of the greatest travellers in the insect world. The butterfly breeds in the USA and Southern Canada, then starts to move south in late August and early September. It flies to wintering grounds in Southern California and Mexico, a distance of some 2,500 km.

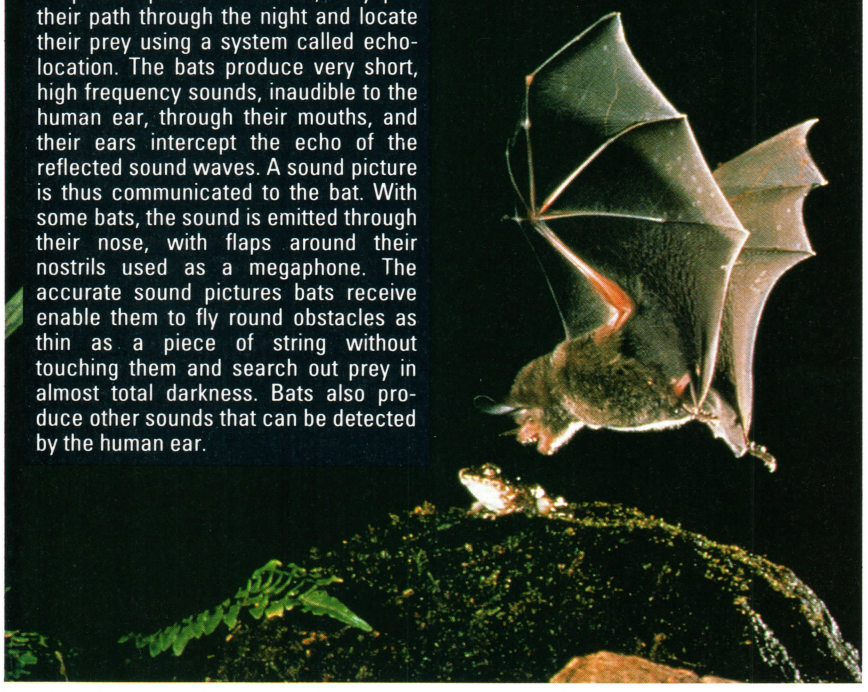
It is possible to track the flights of butterflies by attaching small numbered tags to their wings. Using this technique, a single monarch butterfly was found to travel 1,700 km in just 18 days, an average of nearly 95 km per day. One monarch tagged in Texas was found two days later over 400 km away.

Stephen Dalton/NHPA

EAR-SIGHT



Most bats have very small eyes, sometimes as tiny as a pinhead, capable only of distinguishing between light and dark, but incapable of determining shapes or patterns. Instead, they plot their path through the night and locate their prey using a system called echo-location. The bats produce very short, high frequency sounds, inaudible to the human ear, through their mouths, and their ears intercept the echo of the reflected sound waves. A sound picture is thus communicated to the bat. With some bats, the sound is emitted through their nose, with flaps around their nostrils used as a megaphone. The accurate sound pictures bats receive enable them to fly round obstacles as thin as a piece of string without touching them and search out prey in almost total darkness. Bats also produce other sounds that can be detected by the human ear.



ZEFA

Flying insects can turn stored energy into movement at a much greater rate than any other creatures. A human athlete can increase his metabolic rate by about 20 times, but only for short bursts. An insect can increase its metabolic rate by ten to 20 times and sustain it for several hours. An insect can even reach 50 times its normal metabolic rate for short periods.

Flight endurance

Insects store most of their energy as fat, so the proportion of fat carried by an insect determines its flight endurance. For example, a locust with fat comprising 15 per cent of its body weight will be able to keep flying for about 20 hours. A locust with half the amount of fat would be forced to land after just ten hours.

The method by which birds and insects navigate is not yet fully understood. Birds are known to have a magnetic sense which gives them a sort of internal compass. They also use the positions of the sun and stars.

Insects have prominent, bulging, compound eyes, made up of many individual facets, each of which has its own small lens. This enables the insect to build up a mosaic picture of its surroundings.

Some compound eyes, those of the housefly, for example – have thousands of individual facets. However, the image seen by an insect is nowhere near as detailed as that seen by a bird or a mammal.

Experiments have shown that insects use the position of the sun for navigation, even when it is cloudy. They do this by detecting the plane of polarization of the sun. They must also have an accurate internal body-clock that allows them to compensate for the movement of the sun across the sky during the course of the day.

Flying mammals

The only mammals capable of true flight are bats, although other mammals, such as the flying squirrel, can glide from tree to tree. Bats' wings are large elastic membranes that stretch between the slender arms, legs and tail, and held rigid by elongated 'fingers'. The wing membrane is an extension of the skin from the back, and blood vessels keep it well supplied right up to the extremities.

During flight, the bat's wings do not flap merely up and down. The two front tips of the wings form an elliptical circle in the air as they move down to the back, come forward in front and rise up above the head again.

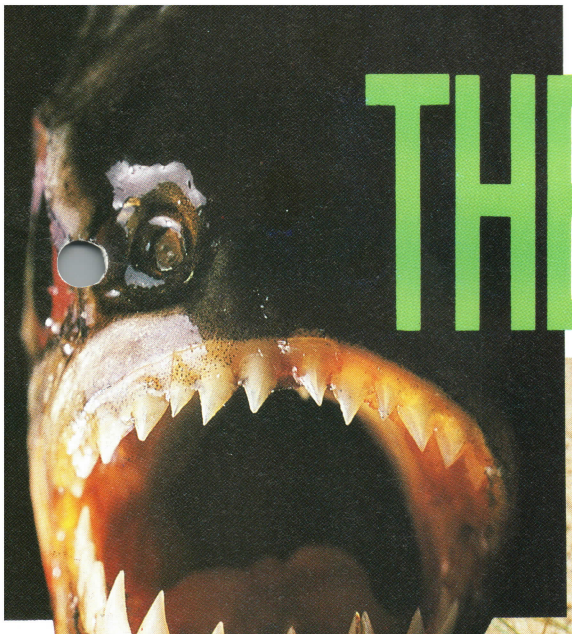
Depending on their size, bats can make from 12 to 18 wing strokes per second. Once it has gained speed by beating its wings, a bat can also glide along.

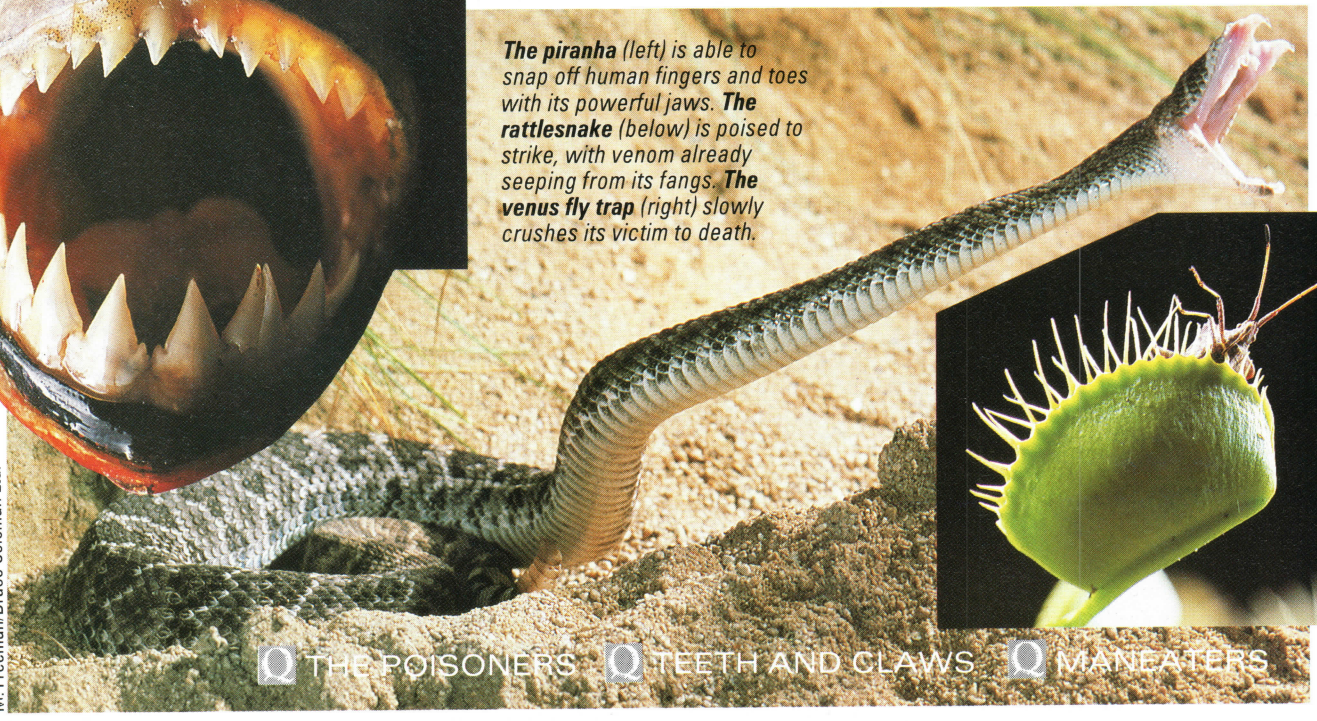
RACING PIGEONS

Pigeon racing developed from the use of homing pigeons for carrying messages – a practice that originated in Roman times. Today's specialized racers are descended from the rock dove, a species once domesticated as a source of food. The rock dove is not a migrator, travelling only as far as is necessary to find a meal. Yet today's racing pigeons have been known to fly distances of almost 2,000 km. Scientists have established that the birds find their way home using an internal compass, and the position of the sun during the day and the stars at night. How the birds establish their starting location when they are transported in closed baskets remains a mystery.

ZEFA

THE PREDATORS





The piranha *(left) is able to snap off human fingers and toes with its powerful jaws.* ***The rattlesnake*** *(below) is poised to strike, with venom already seeping from its fangs.* ***The venus fly trap*** *(right) slowly crushes its victim to death.*

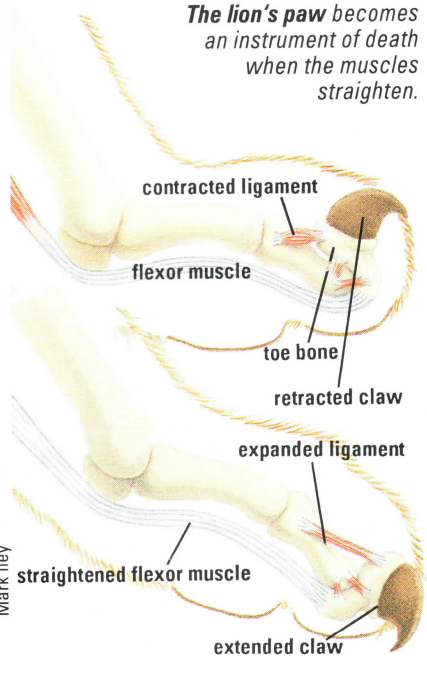
Stephen Dalton/NHPA

M. Freeman/Bruce Coleman Ltd.

UNLIKE HUMANS, MOST creatures kill only for food or in self-defence. Even so, in many instances, their survival depends on their ability to kill – by slashing, biting, crushing, stinging or even electrocuting their victims or attackers.

Among the land mammals, some of the most impressive predators are the big cats. When a lion or tiger pounces, its lethal combination of claws and teeth can bring death to its prey within seconds.

The lion's paw *becomes an instrument of death when the muscles straighten.*



Mark Iley

The claws, normally withdrawn into sheaths to keep them sharp, are dug into the victim to bring it down, then the cat bites through its neck to sever the spinal cord.

Big cats hunt a variety of prey, from small mammals to goats, cattle, zebra and buffalo, but only three species – the lion, the tiger and the leopard – are known to become man-eaters. Not many do, but once they get a taste for human flesh the results can be devastating. In Nepal and northern India, a tigress called the 'Champawat Man-eater' killed 438 people in eight years, before she was cornered and shot.

The largest of the big cats is the Siberian tiger, which can weigh up to 300 kg, but this is small compared with some species of bear. Like the big cats, bears kill with their teeth and claws and will attack a human if they feel threatened.

In terms of average adult size, the biggest bear is the Kodiak or Alaskan brown, which measures some 2.44 metres from nose to tail and weighs up to 675 kg. However, the polar bear – the only large land animal that will track and kill a man for food whenever the opportunity arises – has been known to reach a weight of over 1,000 kg.

Gunter Ziesler/Bruce Coleman Limited

A lioness *in the final stage of the kill. Having caught a wildebeest, she bites into its throat until it suffocates to death.*

Jane Burton/Bruce Coleman Limited

Death in the water

The most notorious aquatic killers are the sharks, but there are many other underwater assassins. In fresh water, the deadliest are the cannibalistic piranhas, which live in the rivers of South America.

These are fairly small fish, usually 30 cm or less in length, but they have immensely powerful jaws with razor-sharp teeth and they attack in gangs. Like sharks, they can sense the blood or the struggles of an injured creature in the water, and they can reduce an alligator to bare bones in less than five minutes.

The marine equivalent of the piranha is the bluefish, which is found in most warm seas. Bluefish wander the oceans in huge shoals, attacking anything edible that comes their way. They have even invaded beaches and attacked

swimmers. The bluefish's killer instinct is so strong that during a feeding frenzy it will eat until full, vomit, and start all over again.

Although most predatory fish use their teeth to catch and kill their food and to defend themselves against attack, some have extra weaponry. Most rays, for instance have thorn-like spines along their tail which can inflict a painful wound on an attacker.

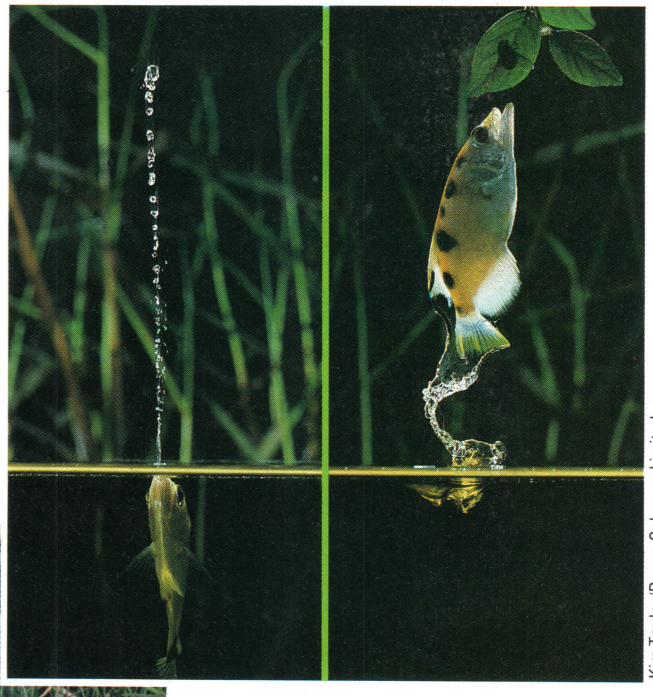
Stings and shocks

In some species, the stingrays, for instance, these spikes are venomous, and many swimmers have suffered painful and even fatal stings from these fish.

Some other rays use electric shocks to stun their prey. The electricity is generated by specialized muscle cells on each side of the fish, and a large torpedo ray can give a considerable shock.

The most powerful electric fish is the freshwater electric eel, another hazard of the rivers of South America. It can deliver a massive shock, strong enough to kill a man.

For centuries, travellers to the jungles of South America have reported giant snakes, anacondas, measuring over 30 metres long. But despite these reports, the longest anacondas recognised by scientists are between eight and nine metres, and the longest snake known is the reticulated python of southeast Asia, which can reach 10 metres in length.

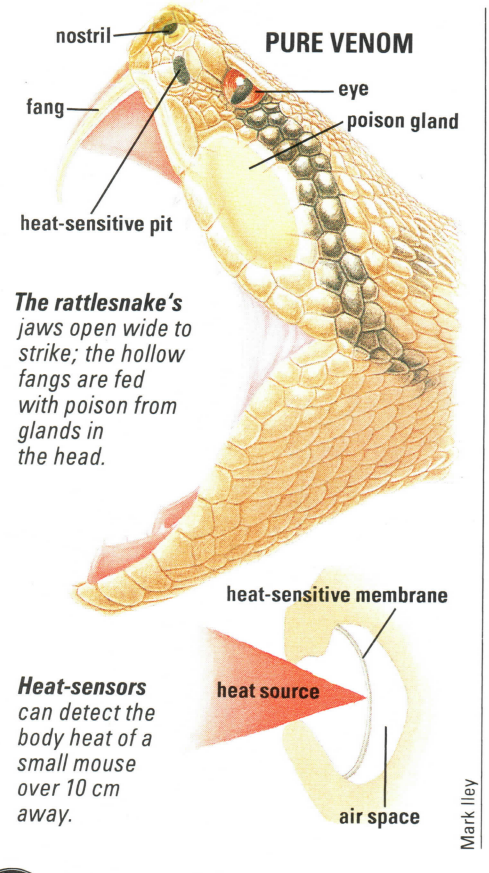


Kim Taylor/Bruce Coleman Limited

An archer fish *shoots an arrow of water with deadly accuracy at its next meal – a low flying insect. Alternatively it may use its powerful muscles to leap out of the water.*

Gunter Ziesler/Bruce Coleman Limited

A rock python *devours a gazelle head first, after squeezing the animal to death with its muscular coils. A meal of this size can last a python for weeks.*



The rattlesnake's *jaws open wide to strike; the hollow fangs are fed with poison from glands in the head.*

Heat-sensors *can detect the body heat of a small mouse over 10 cm away.*

Mark Iley

Deadly reptiles

Anacondas and pythons belong to the group of snakes called constrictors, which kill their prey by suffocating it. They can kill and eat animals as large as pigs, goats and antelopes (and children or small adults), by holding them with their mouths and then coiling themselves tightly around them so that the victim cannot breathe.

When the unfortunate victim's struggles have finally ceased, the snake swallows it whole, a process that can take several hours. After such a meal, the snake may not eat again for weeks or even months.

Most snakes eat smaller meals, however, and feed more often. Some simply grab and swallow prey such as mice and frogs, but many use poison to kill or immobilize their food before they eat it.

When a poisonous snake bites, venom from poison glands in its head flows down, or through, specially adapted fangs in the upper jaw and into the victim.

Some snakes have these fangs at the rear of their mouths, and when they bite the poison runs down grooves in the fangs and into the wound. Others have their fangs at the front of their mouths, and these fangs act like hypodermic needles. The venom flows through channels within the fangs and is injected directly into the victim.

These front fangs may be short and fixed, like those of the cobras and sea snakes, or long but hinged, like those of the vipers. The latter can be folded back against the roof of the mouth when not in use.

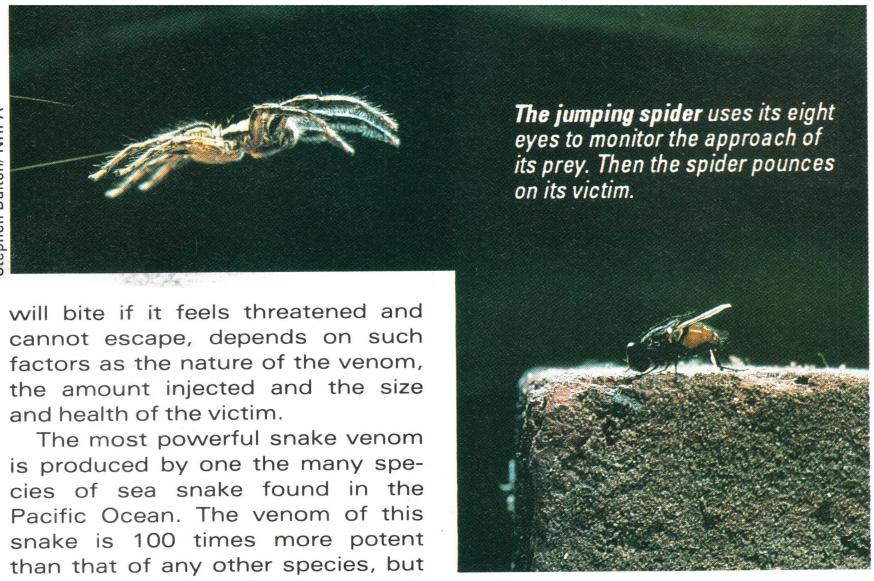
Snake venom usually acts on the victim's central nervous system, causing paralysis and then death. The potency of the venom varies from one species to another, but it is always strong enough to kill the snake's normal prey. Its effect on larger creatures, which the snake

Just amazing!

THE CROAK OF DEATH

COLUMBIAN INDIANS DIP BLOWPIPE DARTS IN POISON FROM THE GOLDEN DART POISON FROG – POISON FROM ONE FROG CAN KILL 2,200 PEOPLE.

Paul Raymonde



Stephen Dalton/ NHPA

***The jumping spider** uses its eight eyes to monitor the approach of its prey. Then the spider pounces on its victim.*

will bite if it feels threatened and cannot escape, depends on such factors as the nature of the venom, the amount injected and the size and health of the victim.

The most powerful snake venom is produced by one the many species of sea snake found in the Pacific Ocean. The venom of this snake is 100 times more potent than that of any other species, but fortunately it is a mild-mannered beast and will only attack a person if provoked. When it does bite, it often does not inject much venom, so the bite is not always fatal.

On land, the most dangerous snake is probably the saw-scaled viper of Africa, the Middle East and India. Just three milligrammes of its venom are enough to kill a human being. This viper is also unusually aggressive when disturbed – unlike most other snakes, which prefer to escape when frightened.

Spider bites

Snakes are not the only creatures that inject poison by biting. Most of the 30,000-odd species of spider have a venomous bite, and some of these are dangerous to humans. Amongst these are the well-known tarantulas, funnel-webs and black widows, and a Brazilian spider, *Phoneutria fera*, which is the most aggressive and toxic of them all – just 0.1 milligrammes of its venom can kill an adult human.

Spiders belong to a group of creatures called the arachnids – a group that also includes the scorpions, which sting with their tails rather than by biting.

The sting in the tail

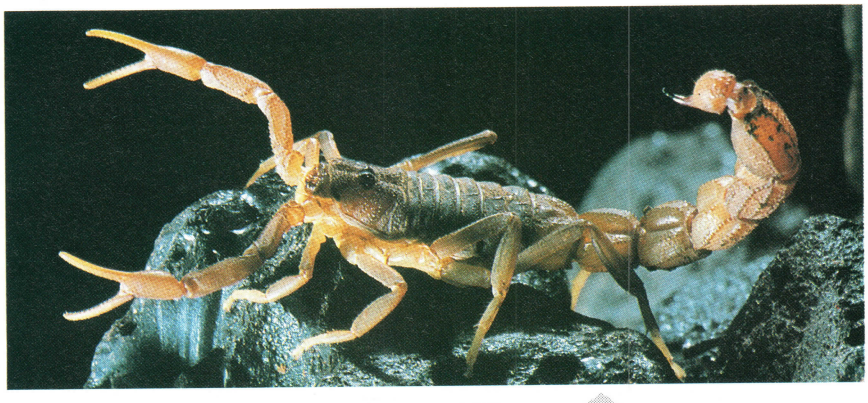
Scorpions, like wasps and bees, have a poison gland and a sting in their tails. Scorpions and wasps use their stings as a hunting weapon as well as for defence, but a bee does not kill to eat and its sting can be used only once. Unlike the smooth sting of a scorpion or wasp, the sting of a bee has a barb, which makes it impossible for the bee to pull it out of its victim after stinging.

Because of this, a bee will only sting as a last resort, usually when it is under attack itself or when it is defending its hive. Some bees, however, seem to feel threatened more readily than others and as a result they act very aggressively.

Some of the most aggressive bees are found in Africa. These also produce a lot of honey, and in 1956 some 170 queens were imported into Brazil to be cross-bred with docile local bees to improve their honey production.

It was thought that the resulting hybrids would combine the honey-making ability of the African bees with the docility of the Brazilian bees. As it turned out, the hybrids were perhaps even more aggressive than their African cousins, and a year later 26 queens and their swarms escaped.

They multiplied rapidly and began spreading northwards at a rate of over 300 km a year. The swarms have so far killed about 200 people and injured many more in their relentless drive towards the USA – they inspired a number of disaster movies such as 'The Swarm'.



Jane Burton/Bruce Coleman Limited

***Scorpions** sting their victims with their tails. The animal is then held in its claws and sucked into the scorpion's mouth.*

HORNS AND TUSKS

Anthony Bannister/OSF

Many animals defend themselves with horns, antlers or tusks. Rhino horns are made of a kind of compressed hair and grow throughout the life of the animal. The antlers of deer are made of a material similar to bone, and are usually shed and regrown every year or so. Elephant tusks are elongated upper incisor teeth, which do not regrow.

KILLER PLANTS

Many plants contain poisons or other unpleasant substances, which deter animals or insects from eating them. But some plants go further, and actually capture and eat insects that land on them. The insects are trapped on or within the leaves, then enzymes produced by the plant digest them and they are absorbed into the plant. The Venus fly trap has hinged leaves that snap shut to imprison any insect landing on it and the sundew has sticky hairs on its leaves that curl round any insect unlucky enough to get stuck to them. The pitcher plant (right) has vase-like leaves with a digestive liquid at the bottom. This digests any insects that fall in down the slippery insides of the leaves.

Michael Viard/Bruce Coleman Limited

Jen & Des Bartlett/Survival Anglia

The Tawny Frogmouth *is a nocturnal bird, which feeds on insects and small animals. At night they crowd together, during the day they sleep in pairs in trees. If the bird senses danger it will stretch its head and neck upwards and stiffen its body so it blends in with the tree.*

Gerald Cubitt/Bruce Coleman Limited

Leaf insects *are relatives of the stick insect. The body and legs are flattened to mimic the leaf on which the insect feeds. It even goes so far as to bear leaf-like veins and a withered look around the edges of the wings. These insects are found in the Tropics.*

Jeff Foott/Survival Anglia

Sea slugs *are often brightly coloured to warn predators that they may be poisonous. Some have adopted the colouring of their diet of seaweed and algae.*

Michael Fogden/OSF

The Horned Frog *pushes its body into the undergrowth to become all but invisible as it lies in wait for a passing mouse or lizard.*

Jeff Foott/Bruce Colman Limited

Monarch butterflies *have bright colouring – nature's warning that they may be poisonous. Other butterflies mimic the Monarch's colouring.*

Jen & Des Bartlett/Survival Anglia

Chameleons *change colour when impulses from the spinal chord are transmitted through nerve fibres to melanophore cells, which then disperse a black pigment.*

Mary Grant/Bruce Colman Limited

The tiger's *striped coat blends well with the strong shadows of the trees and tall grasses found in its jungle habitat.*

Jen & Des Bartlett/Survival Anglia

The Ptmarmigan *adopts seasonal plumage – mottled brown to match the undergrowth in the summer and white to blend in with the snow in winter.*

R.I.M. Campbell/Bruce Colman Limited

The Zebra's stripes *may not appear effective camouflage as it wanders around the scrublands, but when seen through the eyes of predators with no colour vision, they blend almost totally with the branches and bushes that surround them. Travelling in herds also affords protection.*

WEIRD DIETS

Bruce Coleman Limited

***Food** comes in many forms for animals, from human blood for the leech (above) to poisonous snakes for the mongoose.*

THINK OF SOMETHING – anything – and there will be an animal that eats it. Termites eat wood, worms eat earth, mice eat soap, the honey guide bird eats beeswax, rabbits eat their own droppings and cockroaches eat everything, including photographic film.

Leeches suck animals' blood and so does the vampire moth. Birds of prey are usually thought of as meat-eaters, but the Everglades kite feeds on an exclusive diet of water snails, while the palmnut vulture is entirely vegetarian, eating African oil nuts. Most parrots feed on fruits and seeds but the kea, a New Zealand parrot, has a taste for carrion and feeds on dead sheep. Some male butterflies suck roots to extract the sodium that they need to produce sperm.

Some female insects eat their partner while they are mating. Having fertilized the female praying mantis, the male becomes a nourishing meal that will help her produce plenty of eggs. The male empid fly, however, avoids this fate by presenting the female with another insect to eat while they mate.

Even poisonous species are considered a delicacy by certain creatures. The deadly Portuguese man-o'-war is devoured by the ocean sunfish which is immune to its poison. Poisonous rattlesnakes also have their enemies. The king snake – immune to rattler venom – chokes the rattler to death and swallows it whole.

Battles between the cobra and mongoose are legendary. The mongoose, which is not immune to cobra venom, avoids the cobra's fangs as it lunges at it and closes in for the kill. It eats the snake, having (it is thought) first removed the poison glands. Similarly the bee-eater wipes a bee on a branch to squeeze out its sting before swallowing it.

You are what you eat

Much of an animal's appearance and taste is determined by its diet. Lesser flamingos get their colour from chemicals in their food; if captive flamingos are fed on the wrong diet, they turn white rather than pink. Herbivores (plant-eaters) are generally tastier (to humans) than carnivores (meat-eaters). The vegetarian green turtle, for instance, makes excellent soup, while broth made from the carnivorous leatherback turtle tastes disgusting. The eggs of many seabirds, such as the cormorant, have a strong fishy taste because of the birds' diet.

The amount animals need to eat varies enormously. A tortoise is recorded surviving on one banana a

Brian Rogers/Biofotos

***The bee-eater** thrives on ants, wasps and bees – but skilfully crushes out their stings first.*

month, while the Okinawa habu snake can reportedly survive for three years without food. The blue whale, on the other hand, eats about four tonnes of krill a day – one fortieth of its own weight. The mole, which paralyses live worms with a bite and then stores them, eats its own weight in worms every day.

Super stomachs

The giant panda must also eat regularly. It spends about 16 hours a day eating up to 18 kg of bamboo – its only food. It eats so much because it has a poorly adapted intestine.

Most plant-eaters have an intestine 25 times their own body length coiled up inside, but the panda's is only five to six times its body length – a length more typical of a meat-eater. Plant-eaters have long intestines because the cellulose in plants is hard to digest. Cows, for instance, cope with this digestive problem by having four stomachs.

Animals have some unusual ways of finding food. Dung beetles, using their sense of smell, home in towards buffalo dung as it hits the ground. Oilbirds, which have a system of sonar navigation like bats, locate fruit at night by smell.

Dolphins use sonar clicks to locate shoals of fish. The pit viper has a sophisticated method of heat detection which enables it to locate and home in on unseen warm-blooded mammals at night. Frog-eating bats that hunt by sound, distinguish edible frogs from poisonous ones by their mating calls.

The green heron uses bait to attract fish within striking distance by dropping an insect on to the surface of the water. The alligator snapping turtle has a 'worm' (actually a knob of pink flesh) inside its mouth which lures fish into its jaws.

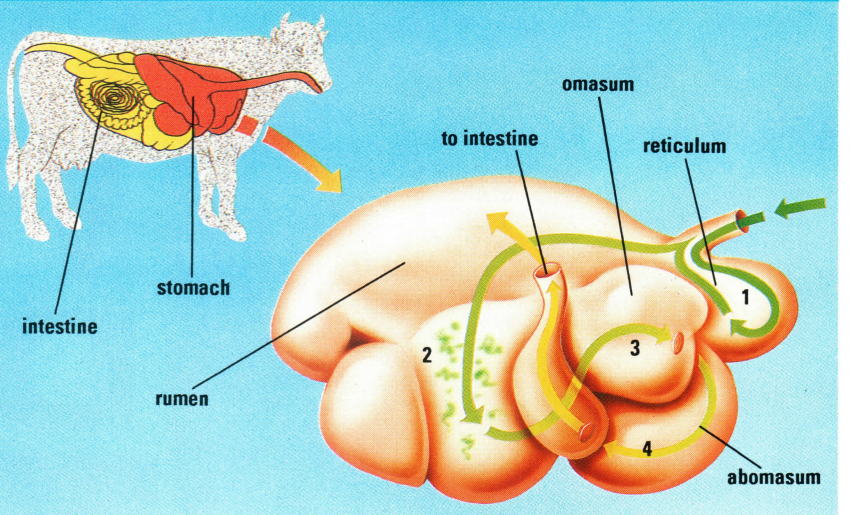
Bees, however, work hard. They make nearly 65,000 trips and visit 45–65 million flowers to produce 1 kg of honey. And a large colony with 80,000 workers eats up to 225 kg of its own home-produced honey each year.

A colony of leaf-cutter ants can strip a fruit tree bare of leaves overnight. But when it comes to sheer destructive power, there is nothing to equal the dreaded locust. A large swarm can chomp its way through 80,000 tonnes of grain and vegetation a day.

Nature Photographers Ltd.

***Foxes** have lost much natural hunting ground to towns – now they must forage where they can.*

IN AND OUT OF THE COW'S STOMACHS



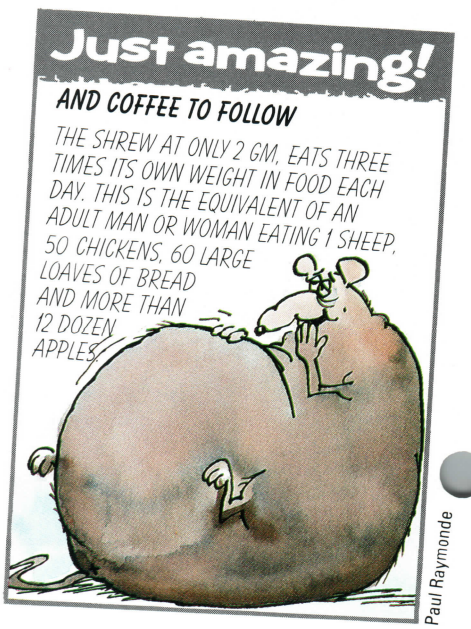
To digest the tough cellulose content of grass, the cow first gives it a quick chew, then passes it through the gullet into the reticulum (**1**). Here, it is formed into balls of cud which are returned to the mouth for a longer chew. The re-chewed grass is then passed on to the rumen (**2**) where bacteria break it down. Next, it is filtered through the omasum (**3**) to the abomasum (true stomach) (**4**), where enzymes break it down into nutrients. The rest is passed into the intestine to be absorbed into the blood or excreted.

Chris Lyon

THE RE-CYCLING EARTHWORM

As the earthworm eats its way through the soil, it performs a most valuable ecological service. Some species form a U-shaped tunnel into which they draw organic matter from the surface to eat, along with some earth. The gizzard grinds this down and after digesting nutrients, the mineral waste is evacuated back up the other end of the tunnel to form the familiar earthworm casts (above). In this way, earthworms may turn round up to 5 tons of soil for every 1,000 sq metres each year, enriching it with the valuable minerals and nitrogen in the ground-up soil they excrete.

Heather Angel



Paul Raymonde

BREEDING THOROUGHBREDS

Trevor Jones/Allsport

Flat racers *usually race as two and three-year-olds, after that many become steeple-chasers where strength and stamina are needed to cover the much longer and more strenuous courses.*

Colorsport

Greyhounds must be *15 months old to race; they usually reach their peak when two and a half or three years old. Few race over the age of five.*

- MATING THE BEST
- A TRAINER'S JOB
- STUD FARMS

RACEHORSES, GREYHOUNDS and racing pigeons are the athletes of the animal world and are as carefully trained as any human athlete. Many, indeed, have more time, care and money lavished on them than most human athletes, which is scarcely surprising as these racing animals are big business.

Animals differ from human athletes because they are selectively bred for success. The basis of all breeding is that the offspring inherit characteristics from their parents and the hope is that they will inherit the best characteristics of each parent. They may also, of course, inherit the worst. To that extent, breeding is potluck. The science of breeding – an inexact science – lies in the continued mating of good animals (and good animals *only*) through several generations to produce excellent offspring that are most likely to be winners. It is important to introduce new blood (unrelated animals) to the family (the bloodline) because the mating of animals that are closely related leads to inbreeding and the development of physical and temperamental weaknesses.

Horses have been bred and raced ever since men first climbed on their backs. The real breakthrough came with the development of the British thoroughbred in the early 1700s. At that time Arab horses were the best racers in the world. Three Arab stallions – the ancestors of many of today's winners – were imported and mated with English mares. The result of these Arab-English crosses was some outstanding racehorses able to beat the best pure Arabs.

Introducing Arab blood to the heavier English horses was a breeding success, producing fast, strong horses – thoroughbreds – that combined the best aspects of both parents: the speed of the Arabs with the stamina of the English. New bloodlines were started and these continue today, although breeders are constantly seeking to improve on them by introducing new blood from thoroughbreds elsewhere in the world.

Training a winner

The story of a great classic winner generally starts at a stud farm where stallions are put to mares. Every horse has its own pedigree

Animal Health Trust

A mechanical treadmill *is used in a controlled environment to help vets to study horses in planned patterns of exercise for carefully calculated periods of time.*

Laurie Morton

Equine pools *can be a boon when dealing with a horse which has sustained an injury. Swimming allows the horse to continue exercise without putting too much strain on its legs. The pools are also used to treat horses who are severely afflicted with arthritis – some have recovered to the point of returning to winning form.*

(parents, grandparents and so on) recorded in a studbook and each owner will select a mate on the basis of its racing performances, conformation (shape) and pedigree. The resulting foal will generally be sold on at the autumn sales as a yearling – a horse that has yet to see two Januarys (Northern Hemisphere) or two Augusts (Southern Hemisphere).

At this stage the horse is an unknown quantity: a half-tonne, million-pound baby that has never been saddled. The trainer's job is to turn the gangly youngster into a racehorse, first breaking it to the leading rein and saddle, then schooling it to trot, canter and finally gallop.

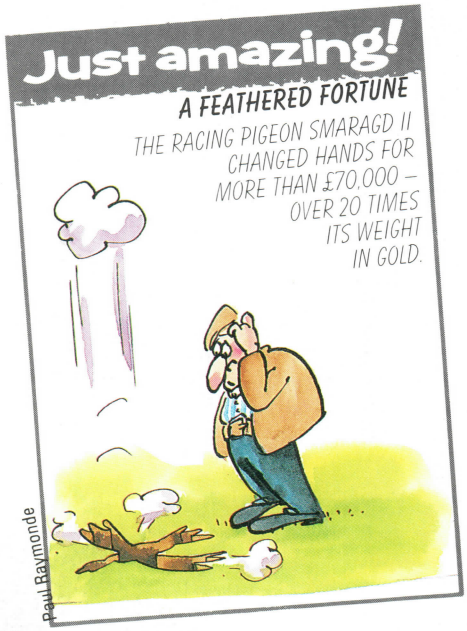
Not until its first race as a two-year-old will the owner and trainer have an idea of the true value of their prodigy. Only the very best will go on to win one of the classic races open to three-year-olds and upwards. Some flat racing horses continue racing until the age of five.

Greyhound racing

The greyhound, bred by man from a wolf-like ancestor, is first recorded being owned by Solomon around 1000BC. However, the modern sport of greyhound racing dates only from 1926 in Britain, having started in 1921 in the USA.

A champion sire, from whom champion racers are bred, is unlikely to produce sons who are also great sires – though it can do if mated to the right bloodlines. The capacity to be a champion sire, as opposed to a champion racer, often skips several generations. Typically the fourth generation – the great-great grandson of the original champion sire – turns out to be a champion sire when mated with a suitable bloodline. The outstanding conjunction of two bloodlines or crosses (a cross is where both the great-great grandson and the dam he mates are descended from the same dog; that is, one bloodline) is known as a 'nick'. This is what all breeders are looking for because the offspring will more than likely be winners on the track. The same applies to champion dams.

Pigeon racing is now an international, multi-million pound business with its own profitable stud farms.



Paul Raymonde

CLEVER PLOYS

A bird with a mate on eggs will race back quickly. Birds are allowed to lay three clutches a year but only two are allowed to hatch. The third clutch is boiled to kill the embryos and returned to the nest. A live chick is slipped under a bird sitting on dead eggs to encourage its mate to speed back.

Those who breed seriously are looking for three things when buying a stock bird: performance, pedigree and a successful breeder behind the bird.

Different breeders have their own criteria for selecting potential winners from which to breed. Commonly, though, they are guided by a good eye ring around the pupil, a well-feathered keel and a quiet heartbeat that can barely be detected. The birds must also be in good health with excellent plumage.

Eyeline Photos

Pigeon racing *is big business these days and some birds fetch thousands of pounds. Prize pigeons are released en masse from a huge custom-built transporter – a far cry from days past when each owner would release his own bird. Exactly how pigeons navigate their way home is still unexplained.*

Even walking takes its toll. *Competitive walking is strenuous and there is always the risk of straining or rupturing a muscle or tendon – an excruciating reality for this athlete.*

Allsport/Bob Martin

SPORTING HAZARDS

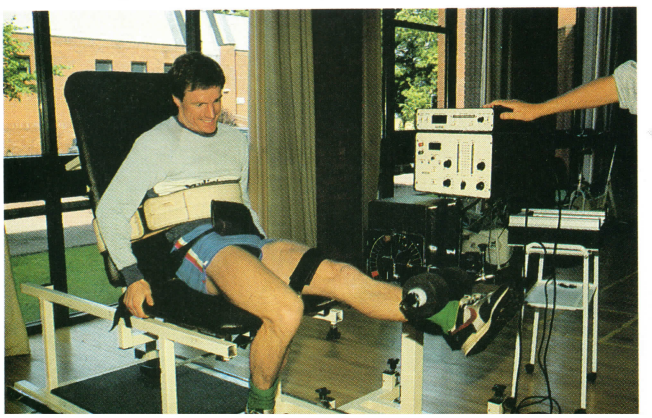
MUSCLE STRAIN | BREAKING BONES | REHABILITATION

A BOXER'S DAMAGED BRAIN is probably the worst consequence of a sporting activity, but most athletes risk some damage through misuse of their bodies or through repeated exertion.

Such injuries can happen simply by overstraining – putting too much stress repeatedly on the same joint, limb or muscle; or they can be the result of an accident; or the deliberate intention to injure on the part of an opponent.

Some injuries happen because a muscle, tendon, ligament or bone becomes overstressed either over a period of time or in one cataclysmic spasm in striving beyond the body's breaking point.

Muscle injuries, known variously as a pull, strain or tear, usually involve some or all of the muscle fibres and connective tissue. The severity is classified according to the amount of tissue involved. Often, the cause is sudden exercising of a muscle before it is properly warmed up. Cold muscles do not contract smoothly and hence overload some fibres. Fatigue and overstressing a muscle to produce more force than it is capable of can also cause injury. A sudden shooting pain is a sure indication. Tendons, the fibrous ends of muscles that join on to bone, can be torn by direct blows or become inflamed through over-use.



After the injury, *the cure. Highly specialized equipment is used to treat sports injuries, as at this rehabilitation centre, where a footballer's recovery is monitored while he does remedial exercises.*

Colorsport

Bone fractures

Stress a bone too much and it can crack or break. When the two ends of a bone are separated from each other, it is known as a complete fracture. When slight cracks occur in the surface of the bone, it is known as a stress fracture.

Complete fractures are most common in the long bones of the arm and leg, whereas stress fractures usually occur in the small bones of the feet and hands.

Footballers and skiers can suffer from broken legs, while rugby players risk breaking their collar bone in a tackle. Cricketers are prone to broken fingers, ribs and arms. Stress fractures can be caused by

training over long distances continually – especially over hard surfaces – or by increasing the intensity of training.

Most serious of all are open fractures, in which the broken end of the bone protrudes through the skin, or if a wound reaches down to it, creating the risk of infection.

All athletes warm up before embarking on their sport. Warming up stimulates blood circulation so that the heart is not stressed by a sudden demand on it. It also raises the temperature so that muscles contract and relax more easily, nerve impulses travel more quickly and synovial fluid flows more freely, making joint movement smoother. Cell metabolism in muscles becomes more efficient and so releases extra energy to work them. The overall effect is a more efficient athlete with a reduced risk of injury.

It is equally important to cool down (that is, reduce the activity slowly and stretch the body gently) after the sport. During heavy exercising, more blood is diverted to the working muscles. After the exercise, it takes a while to return to the heart. Light exercise helps it to get there more quickly and helps prevent nausea, dizziness and fainting.

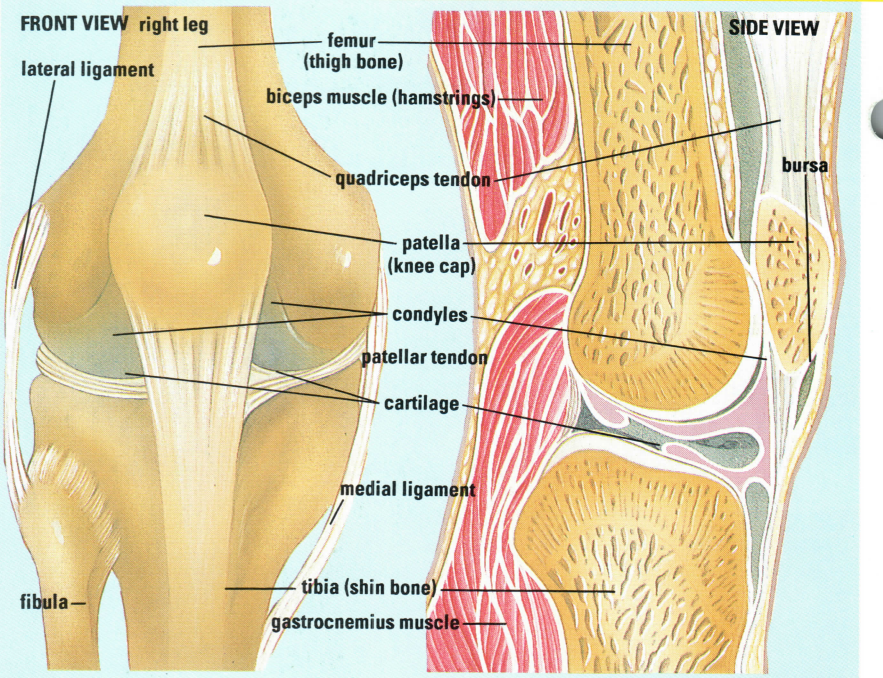
STEROID ABUSE

Courtesy of L & S Research UK, makers of The Cybergenics Total Body Building System

Some athletes take anabolic steroids to increase muscle power, aggression and speed recovery from training. All sports bodies disqualify those who test positively. Taken continuously, even over the relatively short career of a top athlete, anabolic steroids may result in:

- Liver disorders
- Impotence
- Greater risk of heart attack
- Mental disorders

A VULNERABLE JOINT



The knee is the most complicated joint in the body and is used in all sports, which makes it highly vulnerable.

The **patella** can be dislocated by a very sharp twist. It can also be damaged by a direct blow. If one of the **quadriceps tendons** does not function properly, the patella may grate against the cartilage covering the knee joint.

The **patellar tendon** can be strained by overuse or from a sudden injury. It can also rupture under great force or if it is weakened by repeated strains.

A previous injury or internal damage can cause osteoarthritis in later life. The end surfaces of the **tibia** or the **femur** – the **condyles** – wear away.

Abnormal twists or a sudden stress when the knee is bent can tear the **cartilages** between the femur and tibia.

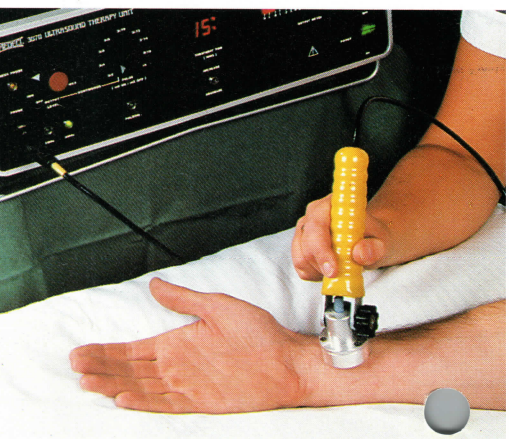
If the foot slips while running, or if it is forced aside in a tackle, the knee may twist, straining the **medial ligament**. Powerful kicks or a fall sideways can also strain this ligament, as will overuse. The **lateral ligament** is injured if the knee is forced outwards when bent.

'Housemaid's knee' is a swelling of the **bursa** – the fluid-filled 'pouch' that protects the patella. Inflammation can be caused by repeated pressure or a sudden, forceful impact.

Laser therapy

Sports injuries are treated by highly specialized means. Much research is constantly being done into the causes, prevention and cures. In addition to surgery, physiotherapy, massage and rest, one of the latest cures is the use of low-level laser therapy (LLLT).

LLLT is used on sprains, inflamed muscles, tendons and ligaments. Even fracture recovery can be speeded up. Depending on the injury, the area is treated with laser energy penetrating to varying depths. The main advantages are fast healing and lack of side-effects.



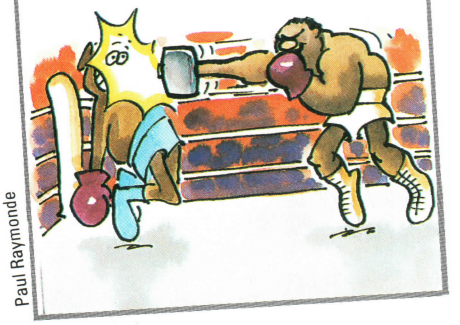
St Bartholomew's Hospital, London/Science Photo Library

Ultrasound *can help reduce pain and heal inflamed tissue, especially around joints. Tiny bursts of high-frequency sound are applied with a probe.*

Just amazing!

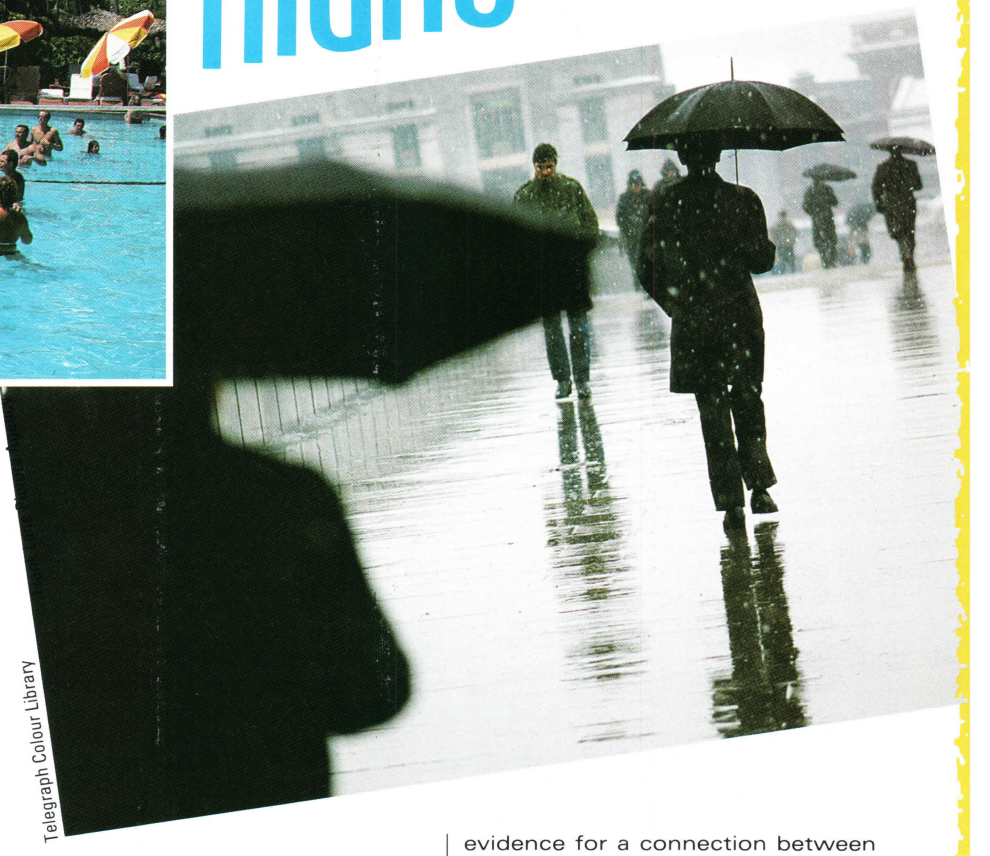
OUT FOR THE COUNT

A PUNCH FROM FRANK BRUNO IS LIKE BEING HIT BY A 6 KG MALLET TRAVELLING AT 32 KM/H. IT PACKS A FORCE OF 6320 NEWTONS – NINE TIMES THE FORCE OF GRAVITY.



Paul Raymonde

HIGHS AND LOWS



Telegraph Colour Library

- SUMMERTIME BLUES
- S.A.D IN WINTER
- FUN IN THE SUN

DO YOU FEEL HAPPIER WHEN the Sun shines and depressed when the weather is grey and dull? Most people say they do. Do you work less well when it's too hot or too cold? People from cooler countries find it hard to work efficiently in the tropics without the benefit of air-conditioning.

In warm countries, hours of work are generally arranged so that workers can take a break, or even a siesta, during the hottest part of the day. Scientists are working to discover the links between the weather and human beings' moods and performance.

The long hot summer

It is generally believed that tempers grow shorter in hot, muggy weather. There is no doubt that 'crimes against the person' rise in the summer, when the weather is hotter, and fall in the winter, when the weather is colder. Research in the USA has shown a relationship between temperature and street riots. The frequency of riots rises dramatically as the weather gets warmer, hitting a peak around 27–30°C.

But is this effect really due to a mood change caused by the heat? Some scientists argue that trouble starts more often in hot weather merely because there are more people in the streets when the weather is good.

Psychologists have also studied how being cold affects performance. Researchers compared divers working in icy cold water at 5°C with others in water at 20°C (about swimming pool temperature). The colder water made the divers worse at simple arithmetic and other mental tasks. But significantly, their performance was impaired as soon as they were put into the cold water – before their bodies had time to cool down. This suggests that the low temperature did not slow down mental functioning directly, but the feeling of cold distracted the divers from their tasks.

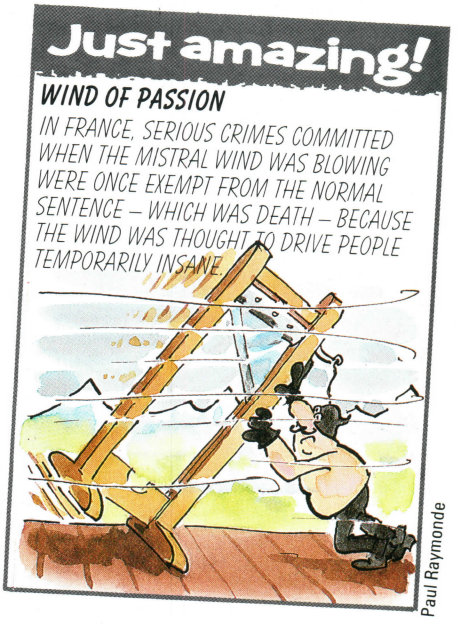
***Hormone levels** – and hence our moods – may be affected by the weather. Gloomy weather can cause depression, but sunshine raises the spirits – as displayed by holidaymakers in a hotel pool in Mexico (top).*

Sunny dispositions

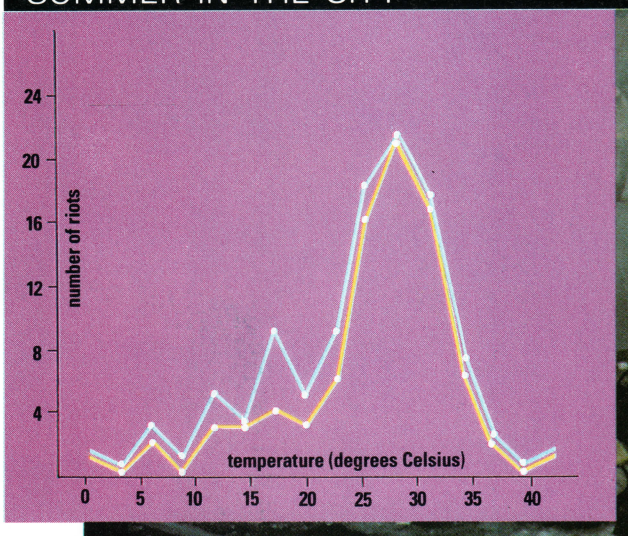
Psychologists have conducted studies showing that people become less sceptical and more optimistic when the weather is sunny. But this does not depend just on the temperature. An American psychologist studied customers in a temperature-controlled restaurant. They gave bigger tips when the Sun was shining and smaller tips when it wasn't, even though the temperature in the restaurant was the same.

A link between weather and mood is made believable by the evidence for a connection between behaviour and the length of the daylight hours. This in turn might involve the level of a hormone called melatonin, produced in the pineal gland in the brain. The amount of melatonin falls with greater exposure to daylight. Research shows that melatonin plays an important part in the seasonal behaviour of certain animals.

For example, food consumption



SUMMER IN THE CITY



Gamma/Frank Spooner Pictures/inset Janos Marffy

City riots *that swept the USA from 1967 to 1971 increased as the weather grew hotter (blue graph). When riots sparked by the murder of Martin Luther King are removed, the trend is even clearer (yellow graph).*

S.A.D SYNDROME

Topham

The dull weather of winter drastically cuts down the amount of sunlight that we experience. Some people are strongly affected by this.

They become so depressed and lacking in energy that their work and social life are seriously affected. This condition has been given the name SAD (Seasonal Affective Disorder). Sufferers can fight back by making the most of any sunlight in winter and by spending a few hours each day under special, full-spectrum lamps. These provide more ultraviolet and blue-green light than ordinary fluorescent and tungsten lights. Some Russian scientists claim that children learn better after being exposed to ultraviolet light.

of stags increases during the winter, reaching a peak in February/March. It falls again to a low point in May, then rises to a peak in September, before dropping to another minimum in November. These changes seem to be triggered by varying melatonin levels.

In the laboratory, hamsters put on more weight when the nights are getting shorter and their melatonin levels are falling. On the other hand, if they are given injections of melatonin, they will stop eating altogether.

It seems that time cues provided by the changing lengths of day and night trigger changes in animals' behaviour – changes that are needed to cope with alterations in weather, and hence food supply, associated with the cycle of the seasons.

People's moods, too, have been shown to react to the length of the daylight hours. Sceptics might say that longer exposure to sunshine puts people in a better mood because they associate it with the happy feelings of holidays and freedom from responsibility.

The belief that rain and murky weather make people more unhappy is borne out by a study in Belgium, which showed that a telephone counselling service gets more telephone calls from people with suicidal feelings when it rains.

Warm feelings

Temperature can affect bodily functions, which in turn may well affect mood and behaviour. The warmer the weather, the fewer children are conceived. A man's sperm count is at its highest when the average air temperature is a moderate 14–16°C and at its lowest at 23°C. Female fertility is also lower at higher temperatures. Perhaps because of this, the frequency of sexual intercourse is also lower at higher temperatures.

Positive ions

When there is a thunderstorm brewing, some people complain of the air being 'heavy' and of feeling irritable, moody and on edge. They may be reacting to the fact that the air can become slightly positively charged when large thunderclouds are generating the intense electrical fields that cause lightning flashes.

The positive charge increases the levels of serotonin (a chemical involved in sending signals in the nervous system). High levels of serotonin in certain areas of the nervous system make people more active and reactive and, possibly, more aggressive.

When certain winds are blowing, such as the Mistral in southern France and the Föhn in southern Germany, mood can be affected – and traffic accidents rise. It may be significant that the concentration of positively charged particles is greater than normal in these winds.

In the UK, 400,000 ionizers are sold every year. These small machines raise the number of negative ions in the air in a room. Many people claim they feel better in negatively charged air.